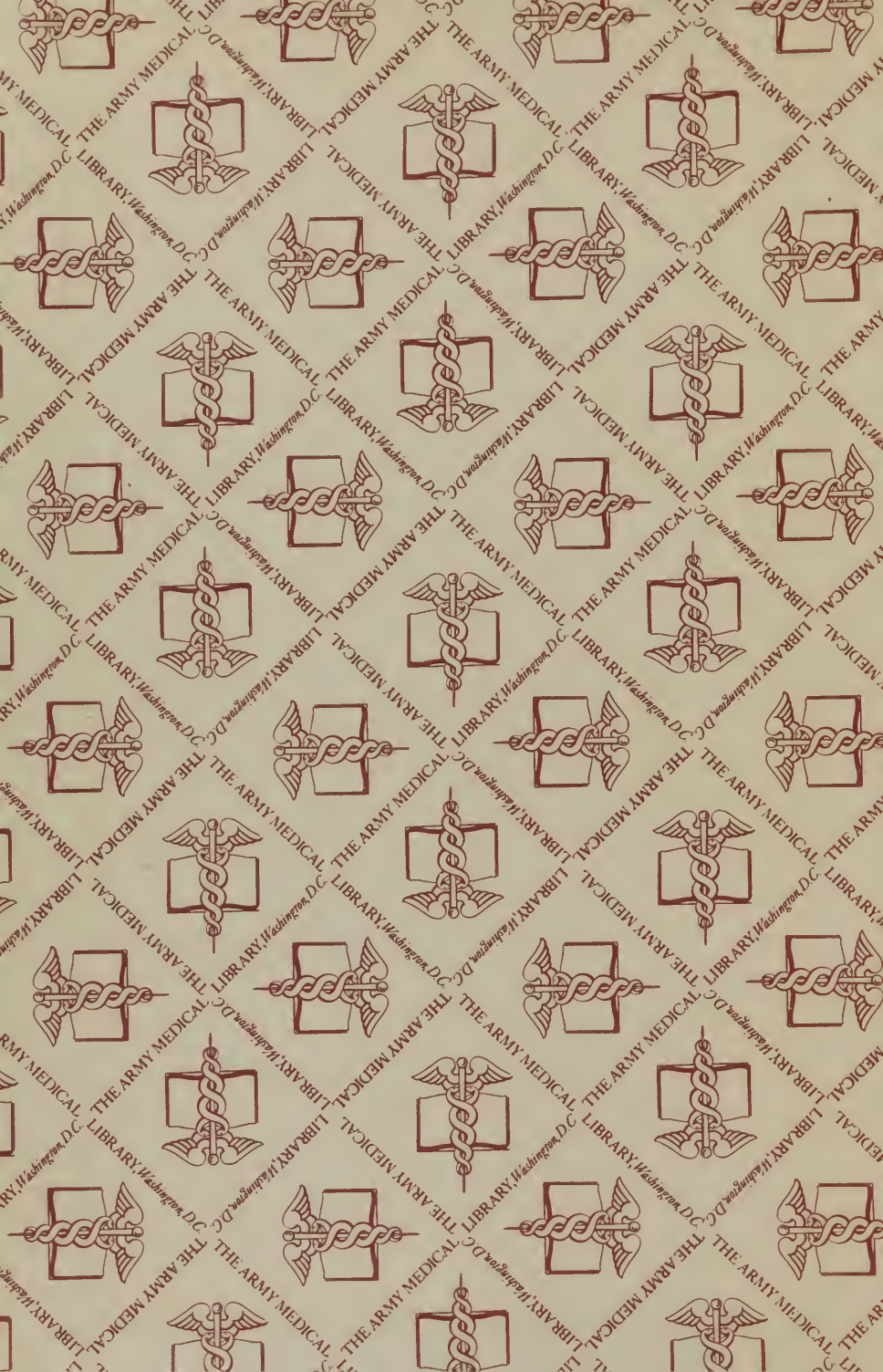
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EXPERIMENTS

UPON

DIGESTION.

BY

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EXPERIMENTS UPON DIGESTION.

An opportunity was lately afforded to the writer of examining and experimenting upon Alexis St. Martin, the Canadian, with a fistulous orifice in his stomach; a man whose name is familiar to almost every medical student as the subject of the experiments upon digestion performed by the late Dr. Wm. Beaumont, of the U. S. Army.

It will be remembered that, when quite a lad, St. Martin received the contents of a loaded gun, accidentally discharged. The charge, consisting of powder and duck shot, took effect in his left side, and after tearing away the integuments, muscles, portions of the fifth and sixth ribs and of the left lung and diaphragm, perforated the stomach, creating a wound through which the contents of the latter organ escaped by an orifice large enough to admit the forefinger. This orifice has never closed, although the surrounding wound cicatrised readily.

The man has enjoyed general good health, and has been the father of a large family, whom he has supported, up to the present time, by hard labor.

With one single exception, that of the Esthonian peasant reported by Grunewald and Schroeder, St. Martin is the only instance in which the opportunity of watching the process of digestion, in an otherwise healthy person, has ever been afforded; the case reported by Circaud in the Jour. de Physiologie, so far as we can learn, never having been experimented upon.*

The experiments performed by Dr. Beaumont are so familiar to every student of physiology, that any analysis of them is uncalled for, even if the limits of this paper permitted it. The object of the present communication is merely to detail the results of recent observations, and compare them with those obtained from other sources.

* Cyc. of Anat. and Phys., Art. Digestion.

Several questions relating to the physiological action of the stomach may be regarded as still unsettled; among these is that relating to the nature of the acid contained in the gastric juice, and the influence of this secretion upon the various alimentary principles as classified by Prout, to wit, saccharine, oleaginous and albuminous food. The present paper will be devoted to the consideration of these points.

It must be premised that the analyses were made upon the fluids obtained from the stomach while digestion was in progress, for that which was withdrawn from the organ while the man was fasting, (that is in the morning, before rising from bed,) was found to be putrescent, although only twenty hours had elapsed after its reception by the writer. The analyses were conducted by the careful hands of Prof. R. E. Rogers, of the University of Pennsylvania, in the presence of the writer, who thus desires to acknowledge the valuable aid received by him.

In every instance, and with all the kinds of food employed, the reaction of the fluid of digestion was distinctly *acid* to litmus paper, while that of the *empty* stomach, (as shown by the introduction of test papers through the fistulous orifice,) and of the fluid obtained by mechanical irritation, was as distinctly *neutral*. The *temperature* of the stomach, while digestion was in progress, was about 100° to 101° Fahr. When empty, about 98° to 99° Fahr.

The fluid for examination was obtained by placing the man upon his right side, and gently introducing a large sized gum elastic catheter, or a small glass speculum. He was then allowed to turn himself towards the opposite side, when the contents of the stomach would readily flow out. In no instance was food allowed to remain in the stomach longer than two hours. The mucous membrane of the empty stomach presented a pale pink color, as described by Beaumont, with the surface lubricated by mucus; when digesting, its color was deepened, and the peristaltic motion could be distinctly seen. During all the experiments St. Martin maintained his usual good health, was in excellent spirits and took his food with appetite.

Previously to the opportunity afforded to Dr. Beaumont by St. Martin's accident, specimens of gastric fluid were obtained by means of sponges attached to strings, as was done by Reau-

mur and Spallanzani; by exciting vomiting after eating, as recorded by Leipzig; by killing animals, while digestion was going on, as was done by Prout and others; or by establishing fistulous orifices in the stomachs of lower animals, as performed by Blondlot, Lassaigne, Bernard and Barreswill, and others since them.

All these observers, from the earliest to the latest, agree on one point, to wit, the existence of an acid reaction in the fluid of digestion; but as to the *nature* of that acid, they differ widely, some contending that it is *organic*, others that it is *mineral;* some that is acetic, lactic, or butyric acid, others that the acidity depends upon the presence of hydrochloric acid, or upon the acid biphosphate of lime. The latter theory, advanced by Blondlot, has been disproved by Dumas, Bernard and Melsens, who have shown, that not only the carbonate, but the basic phosphate of lime, are soluble in gastric juice, as are also zinc and iron, with the evolution of hydrogen gas,—properties which a solution of acid phosphate of lime does not possess.*

The analysis of the fluid obtained from St. Martin by Dr. Beaumont in 1833–4, and submitted to Prof. Dunglison, then of the University of Virginia, showed, as the latter states, the presence of "free muriatic and acetic acids, phosphates and muriates, with bases of potassa, soda, magnesia and lime, and an animal matter, soluble in cold water but insoluble in hot." Dr. Dunglison further states, "we distilled the gastric fluid, when the free acid passed over, the salts and animal matter remaining in the retort. The quantity of chloride of silver thrown down was astonishing."†

Previously to this analysis, in 1824, Dr. Prout had made the same assertion as to the presence of hydrochloric acid, based upon the examination of the contents of the stomachs of rabbits killed while digesting; and Braconnot, in 1835, subsequently to Dunglison, states that he obtained evidences of free hydrochloric acid in gastric juice obtained by sponging the stomachs of animals.‡

More recently, Bernard and Barreswill, Pelouse and Thomp-

* Phys. Chem., by C. G. Lehmann.

† Experiments and Observations on the Gastric Juice, by Wm. Beaumont, M. D., Surgeon U. S. Army.

‡ Annales de Chimie, T. 59, p. 348.

son, have been led to believe, from their own experimental researches, that *lactic* acid is the agent upon which the characteristic reaction of the gastric juice depends, and attribute the presence of hydrochloric acid in the free state to the decomposition of the alkaline chlorides by the lactic acid at a high heat. Hence, supposing *lactic* acid to be present in the fluid of digestion with the chloride of sodium, the fluid which passes over by distillation will, *at first*, be destitute of hydrochloric acid; but as the liquid becomes more concentrated and the temperature rises, hydrochloric acid will pass over.* Lehmann denies the power of hydrochloric acid to decompose the chloride of sodium, but asserts that chloride of calcium is decomposed by lactic acid, even *in vacuo;* and that hence it is not surprising that pure gastric juice should develope vapors *in vacuo*, which, when passed into a solution of nitrate of silver, should form chloride of silver.†

Still more recently, Messrs. Bidder and Schmidt declare, as the result of eighteen corresponding analyses, "that pure gastric juice of carnivora, after eighteen to twenty hours fasting, contained *free hydrochloric acid only*, without a trace of lactic or any other organic acid; while the gastric juice of herbivora contains, with free hydrochloric acid, small quantities of lactic acid, which may, however, be referred to their more amylaceous food."‡ Grunewald's experiments led him to the conclusion that the acid was an organic one; while Schroeder maintains that the fluid obtained by irritating the stomach by peas, owed its reaction to hydrochloric acid.§

Amidst all this conflict of opinion a reconciliation is scarcely to be hoped for; it is suggested, however, that a portion of it, at least, may be owing to the variety of animals experimented upon, and the question may be asked, whether observations made upon the human subject in the healthy condition, should not be relied upon, rather than those derived from experiments performed upon lower animals, in whom the severity of the operation and the emotions necessarily excited thereby, must unavoidably vitiate the results. The difficulty is somewhat relieved

* Carpenter's Human Physiology, Amer. Edit. p. 109.
† Phys. Chem. vol. i., p. 93.
‡ Cyclopædia of Anat. and Phys., part xlvii., Art. Stomach and Intestines.
§ Dissert. Inaug.

by the fact that only *two* acids are involved in the question, and it narrows itself to the decision as to whether they are both present together, or whether one substitutes the other. The following experiments may serve to decide this question.

May 6th, 1856, at 10, A. M.—Two ounces of dry wheat bread were given to St. Martin, which he masticated deliberately and swallowed. At 12½, P. M., the contents of the stomach were removed by Dr. Bunting in the presence of a number of medical gentlemen and students, and carefully preserved for immediate analysis. The reaction was *decidedly* acid, s. g. 1009. Microscopic examination showed large epithelial cells, mucous corpuscles, amorphous granular matter and starch granules, some broken down, others perfect, together with a few cells of cylinder epithelium.

Experiment 1.—A portion of the fluid thus obtained, was subjected to distillation. In the early vapor that came over, no trace of acidity could be detected by litmus paper; the distillate was neutral, neither acid nor alkaline, and did not precipitate with nitrate of silver. The distillation being carried further, so as to concentrate the material in the retort and increase its temperature, the distillate was found to become acid, and a portion being added to a solution of nitrate of silver, a faint precipitate, which was soluble in ammonia, took place. (This experiment has been repeated since, with the material discharged from the stomach, *at will*, after a meal of bread. The distillate became *distinctly* acid, but threw down the faintest precipitate, a mere opalescence, with nitrate of silver. The acid of the distillate gave all the evidence of lactic acid.)

Ex. 2.—A portion of the material from the retort being tested with chloride of barium, gave no visible indication of sulphuric acid.

Ex. 3.—Another portion of the gastric fluid was heated in a porcelain capsule for the purpose of incineration. The vapor that escaped gave no evidence of acidity, but the residue became increasingly acid in proportion as it became more concentrated.

May 9th. Two ounces of bread moistened with water, were introduced into the stomach, through the fistulous orifice. In an hour and a half the contents were withdrawn. The fluid was very viscid, and presented, as before, a decidedly acid re-

action. Some portions of the bread were undissolved, although the greater part had disappeared; sp. gr. not noted. The microscope revealed fewer epithelial cells than in the examination of the previous fluid, some mucous corpuscles and abundance of starch granules, some of which were broken down.

Ex. 4.—A portion of the fluid just obtained was decanted from the bread particles and carefully distilled, without presenting any evidence of acidity to litmus in the fumes. The distillate was acid to litmus, and when tested with nitrate of silver, presented a *very faint* indication of the presence of hydrochloric acid. The residue in the retort, when somewhat concentrated, gave a deep acid reaction.

Ex. 5.—A portion of the same fluid, as in Ex. 4, was gently boiled in a retort; the distillate was acid, and when tested as before, gave the same faint evidence of the presence of hydrochloric acid. The residue, when taken from the retort and examined with litmus, was found more acid than before the distillation. It was then carefully evaporated and examined from time to time, with the effect of manifesting a constantly increasing acidity so long as it remained liquid. The heat was then carried still further, so as to dry but not char the material; on moistening it with water it was found still more intensely acid. Heat was again applied and carried to *incipient* charring, and then the material was moistened and tested again, exhibiting a *diminished* acidity. The same experiment repeated and carried to increased charring, showed, on moistening the residue, a still diminishing acidity, and on heating the residue to thorough charring and until all empyreumatic odor ceased to be given off, it was found that *all* acidity had disappeared.

Ex. 6.—It was suggested that the acid reaction of the residuum might be due to phosphoric acid, and that it might have been decomposed by the heat employed and the carbon which was present. To determine this, another portion of the same fluid was mixed with three drops of a solution of phosphoric acid, and the mixture was carried through the same series of experiments, giving a successively increasing acidity, with this peculiar result, however—that even after the whole material had been thoroughly charred, as before, and still more highly heated, the acid reaction still remained, thus demonstrating that the

acid detected in the product of digestion in the first experiments was *not* the phosphoric.

Ex. 7.—To ascertain whether hydrochloric acid, if present in the free state, could resist the distilling heat and remain in the residuum when concentrated, a minute drop was added to a quantity of water so large as to render its reaction undetectible by litmus ; and a like quantity to the fluid of digestion, and both were distilled. In both cases, a *very* distinct evidence of the presence of the acid was obtained in the distillate by a decided precipitate with nitrate of silver.

Experiments 6 and 7 go to show that the acid of the gastric juice, that at least upon which its most decided action depends, is not phosphoric acid, for it does not resist high heat, as that acid is known to do. It is probably not hydrochloric, nor acetic, for these are both highly volatile and are detected readily in the distillate by nitrate of silver.

Ex. 8.—This experiment was performed in verification of the doubt just stated, that hydrochloric acid is not present in the free state in the fluid of digestion. A portion of all the digestive fluids obtained from St. Martin, and a quantity vomited at will by another individual, were tested with pure deutoxide of manganese, without giving the slightest trace of the presence of chlorine.

Another portion of the digestive fluids was carefully filtered, and a minute trace of chloride of calcium added to it; the material was then tested with oxalic acid, when immediately the white precipitate of oxalate of lime took place. Had any free hydrochloric acid been present, it would have prevented the appearance of the precipitate by dissolving it. To prove this, another portion of the same gastric fluid was filtered, and a minute quantity of hydrochloric acid and chloride of calcium were added to it. The addition of oxalic acid now produced *no* precipitate.*

It thus became a demonstration that the strong acid reaction of these gastric fluids was not due to the presence of free hydrochloric acid. It seems equally clear that it was an *organic* acid, from the fact that it was destroyed by heat, as in Ex. 5 ; and almost certain that it was lactic. To decide this doubt, a portion of the distillate and another of the residue in the retort were tested

* See Lehmann's Phys. Chem. p. 93, vol. i.

with zinc, as recommended by Lehmann,* with the effect of producing the characteristic crystals of *lactate of zinc.*

It will be remembered that in experiments 4 and 8 a faint evidence of the presence of hydrochloric in the distillate was manifested by the reaction with nitrate of silver. It will also be remembered, that Bernard and Barreswill assert that this hydrochloric acid is due to the decomposition of the alkaline chlorides at a high heat. To test this the following experiment was performed:

Ex. 9.—Lactic acid was mixed with chloride of sodium, and the two were heated in a retort. The distillate gave the *faintest* possible trace of opalescence when treated with nitrate of silver. This evidence can scarcely be relied upon, for the solution above described required so high a temperature to produce ebullition, that it was difficult to prevent a spurious distillation of the chloride of sodium along with the vapor, and from this, it is believed, arose the opalescence in the reaction between the distillate and nitrate of silver. If lactic acid can decompose the chloride of sodium, it can only be in very small amount; *chloride of calcium*, as Lehmann has shown, can be decomposed by lactic acid, and if this be present in gastric juice with lactic acid, we may have hydrochloric acid developed by distillation.

May 8th.—A meal of roast beef, with a small portion of salt as a condiment, was given to St. Martin at 2 P. M. At 3½ o'clock of the same afternoon the contents of the stomach were removed. The fluid was viscid, inodorous, presented a flocculent deposit and a marked acid reaction; s. g. 1008. The microscope revealed numerous epithelial cells from the mucous membrane of the mouth downwards as far as the stomach, mucous corpuscles, amorphous granular matter, oil globules in great abundance, and transversely striated muscular fibres, in some of which the sarcolemma was softened and ruptured, and the sarcous elements just liberated.

The gastric fluid was carried through the same series of experiments as those to which the product of bread digestion was subjected, and with a like result. The distillate was distinctly acid, but gave very faint traces of hydrochloric acid. The residuum became most intensely acid as it was concentrated, and

* Phys. Chem. p. 92, vol. i.

the presence of lactic acid was manifested, both in the distillate and the residuum, by the test of the characteristic crystals of lactate of zinc.

From the preceding experiments the following conclusions are fairly deducible:

1st. That the secretions of the stomach when digesting are invariably acid.

2d. That the acid reaction was not due to the presence of phosphoric acid.

3d. That *if* hydrochloric acid was present, it was in very small quantities.

4th. That the main agent in producing the characteristic reaction was *lactic acid.*

It is but just to say that the experiments were conducted with the utmost care and precision, with a single eye to *truth*, and not with a view to support any favorite theory of digestion. So far from this, it may be stated, that the results arrived at are at variance with the doctrines maintained by the writer for many years. Each experiment was repeated several times, so as to leave no room for doubt, and was carefully compared with the results obtained by examination of the fluids discharged at will by another individual.

It is true that this is only one series of observations, and the first that has been published, so far as St. Martin is concerned, since the analyses of Dunglison and Emmett; and now that he has again become a subject for experimentation, perhaps other and different results may be obtained. There may be sources of fallacy, unknown to the writer at the time, which may vitiate the conclusions arrived at; if so, they will be abandoned as readily as those formerly maintained.

> Si quid novisti rectius istis, candidus imperti;
> Si non, his utere mecum!

The next question to be decided was, in regard to the influence of the gastric juice upon various alimentary substances, to wit: *albuminous, amylaceous, and oleaginous.*

It is very commonly accepted among physiologists, that the main business of the gastric juice is to act as the solvent of the albuminous, or nitrogenised articles of food, all the other alimentary principles either undergoing no change, or at farthest only a mechanical sub-division. It was reserved for Mialhe to

show, that whatever albuminous aliment was presented to the solvent, it not only underwent solution, but was converted into a thoroughly new substance, a low form of albumen, and named by him *albuminose*, or, as Lehmann has proposed to call it, Peptone.* The formation of peptone depends solely on the action of the gastric juice, and occurs without the evolution or absorption of any gas, and without the production of any secondary substance.

Whatever article may be selected for the production of peptone, the following properties can always be recognised. When reduced to the solid form by careful evaporation, peptone is a white, or yellowish-white substance; almost tasteless and inodorous; very soluble in water; but insoluble in alcohol of 83 per cent. Its watery solution reddens litmus, and is precipitated by chlorine, tannic acid and metallic salts, but is unaffected by boiling, by acids, or by alkalies. No precipitation or turbidity is produced by the addition of mineral or organic acids, either in a concentrated or in a very dilute state; even chromic acid fails to produce any appreciable effect.†

The *albuminose*, or *peptone*, thus formed by the action of the gastric juice, is not only soluble independently of the gastric juice, but is also capable of absorption, a circumstance which does not obtain in regard to albuminous substances generally, which penetrate animal membranes with difficulty, their diffusion equivalent, according to Graham, being exceedingly low, sugar being 8½ times and kitchen salt 19 times greater than albumen. On this lies the ground for the observation, that protein compounds, apparently all ready for use as nutriment, require a change by the digestive fluids previous to absorption. Without the gastric and intestinal juices, even soluble albumen and casein are taken up in far too little quantities to suffice for the nourishment of the frame.‡

Ex. 10. As the representative of the *albuminous* class, four ounces of rarely done beefsteak were given to St. Martin at 10 A. M., May 5th, after a light breakfast of bread and coffee at 6 A. M., of the same day. No fluid was allowed to be taken in connection with the beef, nor any other article of food.

* Phys. Chem. vol. ii. p. 50.

† Op. cit.

‡ Lehmann, quoted by Chambers, "Digestion and its Derangement."

At 12 M., of same day, St. Martin was subjected to examination. On pushing back the fold of mucous membrane which acts as a valve to the fistulous orifice, a considerable amount of fluid was readily distinguishable in the stomach, mixed with bubbles of air; but no solid matter was visible. About a fluidounce and a half of this fluid was withdrawn from the stomach by a catheter, with the effect of producing nausea which precluded the possibility of obtaining more.

The fluid presented the same reaction as all the others experimented upon; s. g. 1009. Numerous flocculi were visible to the naked eye, looking like the debris of food and mucus. It was almost entirely inodorous, viscid, and to the taste decidedly acid.

The microscope, as in the other cases, revealed amorphous granular matter, mucous corpuscles, granular cells, and a few epithelial cells; a few transversely striated muscular fibres were also beautifully displayed, some almost uninjured, some broken down and with the sarcous elements liberated. Numerous oil globules were also distinctly visible, and a few fibres of yellow elastic tissue. The bulk of the material consumed as food had undergone entire solution, and had wholly lost its characteristic appearance.

A portion of the supernatant fluid was boiled actively, without, however, presenting the slightest trace of coagulation. The mineral acids had no effect upon it while cold, but when boiled with strong hydrochloric acid, the purple color of the protein bodies was distinctly manifested. The addition of acetic acid rendered the fluid rather more clear than before. The action of alkalies upon the fluid was not tried; but Trommer's test gave no evidence of the presence of glucose.

A portion of the dissolved material had doubtless been absorbed, but the quantity that still remained, over and above that withdrawn, was not the least remarkable circumstance in connection with the observation. All recent observers agree in stating, that the quantity of gastric fluid poured into the stomach is many times greater than that of the substance to be dissolved; this fluid, however, it must be remembered, is rapidly absorbed again, taking into the blood with it those alimentary matters which it has just dissolved and converted into peptone.

The conclusion from this observation is, that *the gastric juice is a true solvent for animal food.*

The *oleaginous* class of aliments was but imperfectly represented by the fat more or less commingled with the muscular fibres of the food administered as above. The number of oil globules visible under the microscope seems to confirm the observation of Bernard, that fatty matters undergo no change in the stomach beyond that of disaggregation.

Opinions are more divided as regards the influence of the gastric juice upon the *amylaceous*, or starchy articles of food. It is stated by Mialhe,* that this class of alimentary principles is converted into glucose by the digestive process, and that the saliva is the agent concerned, the conversion being continued even after the starch has descended into the stomach. In this opinion he is sustained by Lehmann, who asserts that grape sugar may be detected in the stomach in fifteen minutes after swallowing balls of starch, or after their introduction through fistulous orifices.† Carpenter also states, that the conversion of starch into sugar may go on in the stomach, but he quotes Frerichs as authority for the belief that it depends on the action of the saliva swallowed, the change not taking place when the œsophagus was tied so as to prevent the deglutition of that secretion.‡

Bernard, on the other hand, denies that any such conversion takes place in the stomach, asserting that the acidity of the gastric juice arrests it, if it have already commenced in the mouth during mastication, or prevents it if it be introduced through a fistulous orifice.‖ Dalton holds the same opinion, which he maintains by experiments with gastric juice obtained from dogs, and by the introduction of starch into the stomachs of these animals through fistulous orifices.§ Both these latter observers, however, state that starch when acted upon by saliva out of the body, is converted into glucose, provided the saliva retain its alkalinity, but that the admixture of gastric juice arrests or prevents it if mixed with it. The following experiments

* Mémoire sur la Digestion, &c.

† Dalton on Gastric Juice, in Amer. Journ. Med. Sci., Oct., 1854.

‡ Human Physiology.

‖ MS. Notes of Bernard's Lectures, also Donaldson on Bernard's recent discoveries, Am. Jour. Med. Sc., Oct., 1851.

§ Am. Jour. Med. Sc. Oct., 1854.

may throw some light upon the subject, the amylaceous materials being represented by wheaten bread.

Ex. 11. On the sixth of May, a portion of wheaten bread was given to St. Martin while fasting, which he masticated deliberately and swallowed. In two hours and a half afterwards a portion of the contents of the stomach was removed for examination. The reaction of this fluid was acid, and the microscopic appearances have been detailed already. (*Ex.* 1*st.*) Suffice it to say, that in addition to epithelial and mucous cells, starch granules, some whole, some broken, were distinctly recognisable.

After allowing the fluid to stand until it had settled, a portion of the supernatant liquid was tested with iodide of potassium and nitric acid, with the effect of manifesting decided evidence of the presence of starch by the production of the characteristic blue color. The same reaction was produced with the tinct. of iodine.

Another portion of the same fluid was subjected to Trommer's test; (solution of sulphate of copper and liquor potassæ;) the result showed the brick-dust red precipitate from the reduction of the oxide of copper, in very considerable quantity.

It may be objected to the above experiments, that dextrine or other organic matters of the fluid were instrumental in producing the reduction of the oxide of copper. ("Cette reaction est une oxydation également commune au sucre, á la dextrine, á la gomme, et á l'alcool. Il est utile d'ajouter encore que l'acide urique, l'urée, et l'albumine peuvent reduire ce reactif.")*

To meet this objection the fluid of digestion of bread was carefully filtered through animal charcoal, by which, as Bernard has shown, all matters, except glucose, are detained. The filtrate when subjected to Trommer's test, again afforded the brick-dust precipitate in large quantities.

Ex. 12. In order to ascertain, if possible, what effect the saliva might have had in producing the glycogenic change in the bread masticated, a portion of bread moistened with water was introduced through the fistulous orifice, and St. Martin was requested to swallow as little saliva as possible, which, as he used tobacco, he had little difficulty in complying with. In an hour and a half afterwards, the contents of the stomach were withdrawn. The same acid reaction was manifest, the same microscopic ap-

* Bernard, Leçons de Physiologie Experimentale Appliquée a la Medicine, 1855.

pearances, and the same solution of the materials were present, although not to the same degree as when the bread was masticated.

The fluid was carried through the same tests with a like result, viz: faint evidences of starch and decided evidences of glucose.

Those who have read the admirable paper of Dr. J. C. Dalton, on "Gastric Juice and its Office in Digestion,"* will remember that he states, that "the presence of gastric juice interferes with Trommer's test for grape sugar," and further, that in animals fed with starch, "no sugar is to be detected at any time" in the product of digestion, and still further, that if gastric juice be added to a mixture of saliva and starch, "there is no trace of sugar, even at the end of three hours, and the starch retains its usual properties." Dr. Dalton's experiments were performed upon dogs, in whom he had established fistulous communications with the stomach. It is possible that the greater acidity of their gastric juice may have prevented the metamorphic change, as the writer has witnessed in saliva acidulated with hydrochloric acid; but in the human subject, if we are to accept St. Martin as evidence, his observations have not been verified, indeed they have been disproved.†

The *conclusions* from the foregoing experiments are, that starchy materials are digested in the human stomach; that human gastric juice does not prevent the conversion of starch into grape sugar; and that this conversion may take place in the stomach, independently of the action of saliva, for, as Bernard has shown, any mucous membrane and some alkaline fluids, as the serum of the blood, possess the same power.

In presenting these experiments to those interested in such matters, it is not claimed for them that they are decisive; they are frankly offered as a contribution towards settling a "quæstio vexata." Of their value, others must judge. Their prosecution was a subject of deep interest to the writer, whose chiefest regret in relation to them is, that the opportunity was too fleeting to enable him to obtain more decided and extensive results.

* Amer. Jour. Med. Sc. Oct., 1854.

†It may be mentioned in passing, that cane sugar was also converted into grape sugar in St. Martin's stomach. In the product of digestion of calves' feet jelly, glucose was distinctly recognisable. The gelatine was unchanged.

Further Experiments upon Digestion. By Francis G. Smith, M.D., Professor of Institutes of Medicine in the Medical Department of Pennsylvania College.

In the Medical Examiner for July and September, 1856, the writer published some experiments performed upon Alexis St. Martin, with the view of determining the nature of the acid of the gastric juice, and the influence of the latter fluid upon various alimentary substances. The conclusions arrived at were, that the acid reaction is due to the presence of *lactic acid;* that nitrogenized food is converted into albuminose; that fatty articles undergo no change beyond minute division; that *amylaceous*, or *starchy materials* (in man) *are converted into glucose* or *grape sugar.*

To the last of these conclusions the objection has been urged, that the glucose manifested in the products of digestion "*existed beforehand in the bread used as food.*"*

To those who did not witness the experiments, such an objection may appear well grounded, particularly as it is well known that glucose is formed in the process of panification; but with those who were present, and who saw the evidences of a much larger quantity of glucose in the fluid of digestion than they ever met with in the examination of bread alone, such objections have less weight.

Granting, however, the justice of the criticism, and feeling great respect for the source from whence it came, but at the same time contending for truth alone, the writer has, during the past month, performed a corroborative experiment, with the assistance of his distinguished friend, Dr. E. Brown-Sequard, who kindly *lent himself* for the purpose, in place of St. Martin, unfortunately no longer within reach.

Dr. Brown-Sequard has, as Montegre had, the faculty of vomiting at will, and thus exhibiting the condition of alimentary articles at any stage of digestion. With the view of determining the action of gastric juice upon amylaceous food, he lent his valuable aid and experimental tact in the following researches.

After a night's fasting, the stomach was thoroughly cleansed by copious draughts of water, and a portion of plain arrowroot, carefully washed before boiling, and subsequently tested for glucose (of which not a trace was

* Prof. J. C. Dalton, in Amer. Jour. of Med. Sci., October, 1856.

visible), was administered. After about thirty minutes had elapsed, the contents of the stomach were ejected by a simple spasmodic contraction, and without nausea. The fluid was distinctly acid to litmus, and gave a copious precipitate of red suboxide of copper, with Trommer's test.

The process was continued with subsequent ejections for nearly an hour, with the same result on each repetition, with the exception that the quantity of glucose detected was, if anything, increased. The fluid was not tested for starch or dextrine.

A portion of the same arrowroot was treated with saliva, and allowed to stand about the same length of time that the previous portions had remained in the stomach. Trommer's test revealed glucose, but by no means in so large a quantity as in the previous experiments.

It may be urged by some that these results are not reliable, inasmuch as the process of digestion was not healthily performed. To this it is answered, that there was no evidence of disorder in the function other than the spasmodic contraction alluded to, and that distinguished physiologists have placed implicit confidence in the experiments of Montegre* and others, of a similar character. Taken in connection with the experiments upon St. Martin, therefore, this one seems to bear out the conclusion then arrived at, that "starchy materials are digested in the human stomach; that human gastric juice does not prevent the conversion of starch into grape sugar; and that this conversion may take place in the stomach independently of the action of saliva." In regard to the last point, it may be observed that the fluid character of the food obviated the necessity for insalivation, as Bernard's experiments have shown, and that the glycogenic change, therefore, could have been but little, if at all, influenced by saliva, the effects of which are declared by Bernard to be nullified by the acid reaction of the gastric juice.

* Adelon and Chaussier, art. "Digestion," in Dict. des Sciences Méd., t. ix, pp. 422–3; Stevens, De Alimentorum Concoctione; Spallanzani, Exper. sur la Digestion.


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